"Atmospherical Radio-activity in High Latitudes." By George C. Simpson, B.Sc., 1851 Exhibition Scholar, Owens College, Manchester. Communicated by Arthur Schuster, F.R.S.

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In 1901 Elster and Geitel first showed that a wire stretched out in the open air and charged to a high negative potential becomes radio-active; this observation has since been repeated by others, and the discoverers themselves have undertaken a series of daily measurements extending from December, 1901 to December, 1902. As the geographical distribution of the atmospheric radio-activity is at present entirely unknown, the observations which I have been able to make here in Karasjoh (Norway, 69° 20′ N., 25° 30′ E.), by the courtesy of the Commissioners for the 1851 Exhibition Scholarship, must be of considerable interest.

In my measurements I have used the method described by Elster and Geitel in the 'Physikalische Zeitschrift.'* A wire was stretched between an insulator in the open and another in my living room, the part exposed to the open air, 10 metres long, could be detached from the rest. The wire was charged to a negative potential by means of a small influence machine, built on the principle of a Kelvin replenisher and driven by a weight; by means of a variable high resistance, consisting of a strip of ebonite, one side of which had been rubbed with a black-lead pencil and so mounted in a tube that an earth-connected pad could move along it, the potential of the wire could be very easily regulated. In all my observations the potential was maintained at about 2250 volts, never rising above 2500 and never falling below 2000. The wire after being charged for 2 hours was removed to have its radio-activity determined; this was done by wrapping it round a cylinder of wire netting which fits inside the "protection cylinder" of an Elster and Geitel dissipation electrometer, which for this special purpose is closed at the bottom as well as the top; the rate at which the electrometer is discharged gives a measure of the induced radio-activity. Elster and Geitel have chosen the following as the arbitrary unit of the induced radio-activity. "The activity of the air is put equal to 1 when, after a 2 hours' exposure, a metre of the wire reduces the potential of the dissipation cylinder by 1 volt in 1 hour." The radio-activity when expressed in this unit is denoted by A in the accompanying tables.

The mean value of the radio-activity at Wolfenbüttel in mid-Germany, as determined by Elster and Geitel during the year 1902, was 18·6, the individual values varying between 64 and 4. A complete discussion of the effect of the different meteorological elements is given in the original paper.†

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* Vol. 3, p. 305, 1902.

† 'Physikalische Zeitschrift,' vol. 4, p. 526, 1903.

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Table I.—Details of the Observations.

Date. 1903.	Observations made at 7.30 A.M.	Radio-activity (A), weather and potential gradient (P), between 9 and 12 A.M.	Observations made at 1.30 P.M.	Radio-activity (A), weather and potential gradient (P), between 3 and 6 P.M.	Observations made at 7.30 P.M.	Radio-activity (A), weather and potential gradient (P), between 9 and 11 P.M.
Nov. 23	B. 722·8 T. −3°·0 W. 0	**A** = **48.** P. 101. Fine but cloudy.	B. 724·3 T. −1°·2 W. 1 S.	**A** = **42.** P. 83. Little snow falling.	B. 724·6 T. −4°·2 W. 0	**A** = **126.** P. 52. Little snow falling. Aurora visible through clouds.
,, 24	B. 723·0 T. −6°·0 W. 1 N.	**A** = **36.** P. 87. Had snow in the night. Clouds 8—6.	B. 725·0 T. −6·0 W. 2 S.	**A** = **54.** P. 152. Clear, clouds 5—0.	B. 726·5 T. −8°·8 W. 0	**A** = **42.** P. 307. *Clear*, cloudless. A little aurora light in N. until 10.30.
,, 25	B. 727·7 T. −28°·0 W. 0	**A** = **78.** P. 136. Cloudless, cold morning.	B. 728·6 T. −32°·3 W. 0	**A** = **72.** P. 381. Cloudy, started to snow at end of observation.	B. 729·3 T. −25°·4 W. 0	**A** = **150.** P. 288. Cloudless evening, but no aurora visible.
,, 26	B. 731·5 T. −30°·0 W. 0	**A** = **114.** P. 278. Clear, cold, cloudless day.	B. 734·3 T. −34°·7 W. 0	**A** = **150.** P. 387. Cloudless, faint aurora arch all the time.	B. 736·0 T. −37°·4 W. 0	**A** = **138.** P. 331. Aurora and clouds.
,, 27	B. 731·0 T. −30°·0 W. 0	**A** = **78.** P. 474. Overcast, with thin clouds, which cleared away at 12 o'clock.	B. 732·0 T. −33°·0 W. 0	**A** = **144.** P. 236. Clear, cold, cloudless. No aurora visible.	B. 733·6 T. −32°·0 W. 0	**A** = **294.** P. 156. At 8 o'clock aurora was visible as diffused light in the north, from 8—11 it could only be seen by aid of the spectroscope.
,, 28	B. 728·1 T. −33°·0 W. 0	**A** = **18.** P. 276. Overcast, with snow falling in fine flakes. Wire became covered with fine coat of rime.	B. 731·0 T. −22°·4 W. 0	**A** = **54.** P. 302. Fine, but completely overcast.	B. 730·2 T. −17°·8 W. 0	**A** = **126.** P. 108. Snowing at first, but, during observation, it stopped, and the clouds broke a little, but the sky remained mainly overcast.

„ 30	B. 735·1 T. −19°·8 W. 0	**A** = **66.** P. 70. Very low clouds, or raised fog, snowed a little towards end.	B. 734·5 T. −15°·6 W. 0	**A** = **84.** P. 110. Sky about eight-tenths overcast.	B. 733·4 T. −19°·5 W. 1 N.	**A** = **228.** P. 147. Haze over the sky. No aurora visible.
Dec. 1	B. 737·0 T. −33°·0 W. 0	**A** = **60.** P. 312. Bright, cloudless, cold.	B. 739·3 T. −34°·0 W. 0	**A** = **102.** P. 279. Air filled with ice crystals.	B. 740·0 T. −35°·0 W. 0	**A** = **72.** P. 248. Air filled with ice crystals, and wire became slightly coated with frost.
„ 2	B. 741·7 T. −35°·2 W. 0	**A** = **144.** P. 278. Sky clear until about 7 o'clock in the morning, after which low clouds.	B. 742·5 T. −30°·0 W. 0	**A** = **36.** P. 264. Mist, wire became coated with a thin layer of frost.	B. 741·7 T. −27°·6 W. 0	**A** = **18.** P. 350. Misty, wire became thickly coated with rime.
„ 3	B. 741·0 T. −18°·5 W. 0	**A** = **54.** P. 142. 1st hour misty, 2nd hour clearer; wire obtained thin layer of frost.	B. 748·8 T. −19°·4 W. 0	**A** = **120.** P. 115. Overcast, thin coat of frost on wire.	B. 741·5 T. −24°·5 W. 0	**A** = **126.** P. 153. Air filled with ice crystals. Thin coat of frost on wire.
„ 4	B. 738·0 T. −14°·5 W. 1 E.	**A** = **84.** Overcast, with a little snow falling.	B. 736·3 T. −7°·0 W. 3 S.	**A** = **54.** Heavily overcast, with a high wind (3—4 S.E.).	B. 736·8 T. −1°·8 W. 1 S.E.	**A** = **24.** Negative P. Heavily overcast, with high S.E. wind.
„ 5	B. 739·4 T. 1°·7 W. 2 S.	**A** = **18.** Negative P. Dull, overcast, high wind	B. 742·2 T. −0°·2 W. 3 S.	**A** = **18.** Negative P. Overcast, but not so heavily as in the morning; high wind.	B. 742·2 T. −1°·0 W. 3 S.	**A** = **24.** Negative P.G. Overcast, high wind.
„ 7	B. 738·0 T. +1°·0 W. 1 S.E.	**A** = **144.** P. 46. Overcast, with a few breaks in the clouds.	B. 740·2 T. +0°·5 W. 1 E.	**A** = **78.** Clear, with aurora.	B. 742·6 T. −4°·4 W. 1 E.	**A** = **126.** P. 83. Overcast.
„ 8	B. 745·0 T. −3°·8 W. 1 S.W.	**A** = **36.** P. 91. Overcast.	B. 747·4 T. −4°·2 W. 2 S.	**A** = **48.** P. 71. Overcast.	B. 750·7 T. −8°·4 W. 1 E.	**A** = **136.** P. 91. During exposition clouds became much thinner, so that at end the moon and a few bright stars could be seen.

Table I.—*continued.*

Date. 1903.	Observations made at 7.30 A.M.	Radio-activity (A), weather and potential gradient (P), between 9 and 12 A.M.	Observations made at 1.30 P.M.	Radio-activity (A), weather and potential gradient (P), between 3 and 6 P.M.	Observations made at 7.30 P.M.	Radio-activity (A), weather and potential gradient (P), between 9 and 11 P.M.
Dec. 9	B. 754·0 T. −23°·8 W. 0	**A = 84.** P. 124. At first only high transparent clouds, but it soon became overcast and remained so.	B. 755·8 T. −17°·8 W. 1 S.	**A = 84.** P. 127. Heavily overcast, with a little snow.	B. 752·0 T. −10°·0 W. 0	**A = 174.** P. 96. Overcast, with a little snow.
,, 10	B. 751·0 T. +0°·8 W. 1 S.E.	**A = 138.** P. 33. Overcast, but at times breaks could be seen in the clouds and a very little rain fell.	B. 753·0 T. −2°·0 W. 0	**A = 90.** P. 87. Overcast, with a warm S. wind.	B. 753·2 T. 2°·5 W. 0	**A = 198.** P. 82. Overcast, with a warm S. wind.
,, 11	B. 753·6 T. 1°·5 W. 1 S.	**A = 168.** P. 48. Overcast, with a few clear patches.	B. 754·5 T. 1°·0 W. 2 S.	**A = 48.** P. −39. Heavily overcast.	B. 756·0 T. −1°·3 W. 1 E.	**A = 66.** P. − 45. Heavily overcast.
,, 12	B. 756·2 T. −7°·0 W. 1 E.	**A = 60.** P. 194. Clouds 7.	B. 754·6 T. −4°·5 W. 0	**A = 60.** P.G. 148. Overcast, but at times a few stars could be seen.	B. 754·4 T. −5°·0 W. 0	**A = 78.** P. 192. Clear, cloudless evening. A very little aurora light visible at commencement, but it soon disappeared.
,, 13	B. 755·8 T. −16°·8 W. 0		B. 753·4 T. −10°·0 W. 0		B. 752·0 T. −8°·8 W, 0	**A = 150.** P. 459. Wire exposed during the most brilliant aurora display we have yet had.

,,	14	B. 755·3 T. −12°·0 W. 0	**A** = **102.** P. 243. Overcast, but clouds are not quite so continuous, so that a little blue can be seen between.	B. 752·0 T. −9°·0 W. 0	**A** = **72.** P. 330. At first overcast, but clouds soon disappeared. No sign of aurora. Thin coat of frost on wire.	B. 756·0 T. −18°·0 W. 0	
,,	15	B. 748·8 T. −6°·7 W. 0	**A** = **78.** P. 150. Bright morning with thin high clouds.	B. 749·0 T. −11°·2 W. 0	**A** = **84.** P. 133. Overcast.	B. 743·6 T. −8°·2 W. 0	**A** = **102.** P. 265. Snowing from very thin clouds, so that at times bright stars were visible.
,,	16	B. 745·0 T. −8°·2 W. 0	**A** = **174.** P. 115. Overcast, with thin clouds.	B. 744·7 T. −8° W. 0	**A** = **138.** P. 83. Overcast, with a little snow towards end.	B. 744·7 T. −7°·5 W. 0	**A** = **126.** P. 163. At first overcast, but towards end sky cleared and a little aurora light became visible.
,,	17	B. 749·5 T. −18°·5 W. 0	**A** = **66.** P. 310. Clear cold morning. No clouds in 1st hour, thin ones in 2nd hour. Thin coat of frost on wire.	B. 753·2 T. −21°·0 W. 0	**A** = **384.** P. 168. Overcast, with thin clouds, bright stars visible every now and then towards end.	B. 754·5 T. −23°·0 W. 0	**A** = **432.** P. 106. Clear, cloudless evening. No aurora visible.
,,	18	B. 750·0 T. −17°·3 W. 0	**A** = **204.** P. 116. Cloudless the greater part of time, just a few (1—2) thin high clouds at beginning and end.	B. 747·2 T. −15°·0 W. 1 S.	**A** = **66.** P. 235. Overcast, with thin clouds, through which stars can be seen.	B. 743·5 T. −7°·0 W. 2 N.W.	The wind having risen to a gale, observations were impossible.
,,	19	B. 747·1 T. −9°·5 W. 2 N.W.	**A** = **36.** P. 81. Clouds vary between 3 and 6. Little snow at end.	B. 748·2 T. −11°·6 W. 1 S.	**A** = **42.** P. 324. Cloudless, no aurora.	B. 750·0 T. −18°·5 W. 0	**A** = **21.** P. 461. Mainly cloudless, but a few clouds appeared in the N. towards end. Thin coat of frost on wire.

The first few measurements which I made having shown that the radio-activity is very much greater than in lower latitudes, I determined to make a thorough investigation of it. On November 23, I started a series of measurements of the radio-activity, taking three observations a day; the first in the morning between the hours of 9 and 12, the second in the afternoon between 3 and 6, and the third in the evening between 9 and 11; the series continued uninterrupted for 4 weeks. The results are given in full in Table I, when the following symbols are used:

B = height of barometer in centimetres.
T = temperature in Centigrade degrees.
W = estimated velocity of wind, the direction being added.
P = potential gradient measured in volts per metre.

It will at once be seen that the numbers are very much higher than the corresponding ones for Germany, the mean for the month being 102, which is nearly six times as great as the German mean (for the year); and the highest value, 432, being nearly seven times greater than the German highest. To turn now to a closer investigation of the numbers, Table II shows that there is a marked daily period.

Table II.—Mean and Maximum Values of **A** for each Week.

	Morning **A.**		Afternoon **A.**		Evening **A.**		Mean of three.
	Mean.	Max.	Mean.	Max.	Mean.	Max.	
Nov. 23 to Nov. 28 ..	**62**	114	**86**	150	**146**	294	**98**
Nov. 30 to Dec. 5 ...	**71**	144	**69**	120	**82**	228	**74**
Dec. 7 to Dec. 12 ...	**105**	168	**68**	90	**129**	198	**101**
Dec. 13 to Dec. 19 ..	**110**	204	**131**	384	**166**	432	**136**
Mean for month ...	**87**		**88**		**131**		**102**

The maximum falls in the evening, there being little difference between the morning and afternoon means. Not only is the mean value greatest for the evening, but the absolute maximum falls in the evening each week, and on 13 out of 22 days on which three observations were taken the evening values were the greatest.

It would be of interest to find the relation, if any, between the radio-activity and the other electrical conditions of the atmosphere; but my observations of the dissipation and the ironisation of the air are not sufficiently complete for a rigid comparison, and so must be left for future investigation. Table III gives the relation between the radio-activity and potential gradient. The mean potential gradient for the period of each exposure having been taken with a self-registering electrometer, the values of the radio-activity for each interval of 50 volts meter have been put together and the mean taken.

Table III.—Radio-activity and Potential Gradient, measured in Volts per Metre.

	Negative pol. grad.	0—50.	50—100.	100—150.	150—200.	200—250.	250—300.	300—350.	350—400.	400—450.
No. of observations.	6	3	13	17	8	4	6	8	2	3
A mean	**33**	**150**	**96**	**140**	**150**	**96**	**84**	**61**	**111**	**83**
A maximum.......	66	168	198	432	384	144	144	138	150	150

As can be seen, there is no direct relation between the radio-activity and the potential gradient.

To come now to the effect of the meteorological elements, Table IV shows that temperature and radio-activity are not closely related.

Table IV.—Radio-activity and Temperature.

Temperature °C. ..	−40° to −30°	−30° to −20°.	−20° to −10°.	−10° to 0°.	0° to 10°.
No. of observations.	12	10	17	25	8
A mean	**127**	**166**	**80**	**82**	**110**
A maximum	294	432	204	174	198

Nor does the barometric pressure appear to have any great influence.

Table V.—Radio-activity and Barometer.

Barometer	720—730.	730—740.	740—750.	750—760.
No. of observations...	10	18	23	20
A maximum.........	**66**	**109**	**85**	**137**
A mean.............	180	294	204	432

The only meteorological element which appears to have a direct influence on the atmospherical radio-activity is the amount of cloud. To show this I have divided the observations into three classes: 1st Sky clear, or nearly so; 2nd Detached clouds; 3rd Sky completely overcast, and taken the mean for each class. The results are given in Table VI.

Table VI.—Radio-activity and Clouds.

Clouds.	Clear sky.	Detached clouds.	Completely overcast.
No. of observations ...	18	26	27
A mean.............	**130**	**107**	**76**
A maximum.........	432	384	198

There does not appear to be any close connection between the aurora and the radio-activity, the greatest value of the radio-activity having been obtained when no aurora was visible.

During the whole time these observations were being taken the sun did not rise above the horizon. The time used was mid-European, local mean time being 42 minutes ahead.

The place of observation is 140 metres above sea-level. The ground for a hundred miles round is hard frozen to a great depth and covered with a coating of snow the average depth of which is over 2 feet. Sudden changes in radio-activity are sometimes observed to take place, as, for example, on December 17, when with a rising barometer the activity rose for a few hours from the low value of 66 to the exceptionally high one of 384. There is some difficulty in reconciling these observations with Elster and Geitel's view that the activity is entirely due to a diffusion of a radio-active emanation from the soil.